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ABSTRACT

Described is the Individually Prescribed Instruction program in science for kindergarten through ninth grade. Five goals of the program are discussed: student self-direction, student co-evaluation, positive attitudes, skills in inquiry, and scientific literacy. The organization of the program by developmental levels and organizing themes for content development are outlined. Learning resources (materials and activities) are listed and related to the attainment of the goals. Individualization is discussed in terms of self pacing and student selection of "alternative pathways". (EB)

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AN INDIVIDUALIZED SCIENCE LEARNING SYSTEM FOR THE 1970's*

Two ideas often discussed these days in educational circles are individualization and relevance. The two ideas are not unrelated. Relevance refers to how well an educational program or a course of study is matched to the needs, interests and circumstances of the student. Individualization of instruction suggests a practicable way to increase the relevance of the student's learning experiences in school. Giving attention to both individualization and relevance, Individually Prescribed Instruction (IPI), offers a model for individualization and an instructional system that has become operational during the past five years through the work of the Learning Research and Development Center at the University of Pittsburgh. IPI Science, currently being developed as a part of the IPI effort, is an individualized learning program designed for maximum relevance to each student and to the fast-changing circumstances of today.

What are some implications of living in a world that science and technology are rapidly transforming? Perhaps the extent and rapidity of this transformation is not generally appreciated, even by many educators. Consider some realistic projections. By the time children now entering elementary school finish high school, there will be colonies of men on the moon. By then also, parents will be able to choose in advance the sex of the child they wish to have. Within the next few decades, men and women will be able to live, work, or spend a vacation in an operating community at the bottom of the sea or in a space station orbiting high above the earth. New drugs will be available to prevent now-prevalent diseases, to enhance memory, to modify intelligence, to regulate

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desire, and genetic engineering will make it possible to produce new organisms, including human beings, according to specifications. These possibilities and others that can now be foreseen will be realities in the world in which today's elementary-school children will live.

These projections about the world in the not-too-distant future may even make most of today's adults feel somewhat uncomfortable. Few of us are ready to face up to the dramatic changes that the rapid advances in science and technology are about to bestow on us. We are not ready for these changes because they are unprecedented in the experience of man and because, very often, our own education did not include a meaningful encounter with scientific ideas or an involvement in the processes of scientific inquiry. When there are these gaps in a person's education, he must face almost nakedly a world where the innovations due to science and technology are a main theme of life. That kind of world will confront today's children throughout most of their lives. They could be in deep trouble if they were to be as innocent about science as many adults now are.

An important consequence of the technological transformation of society is the alteration of the accustomed pattern of occupations and careers. No longer will a person choose a career specialty as a youth, be trained for it in school, and persue it throughout his life. Rather, the career of a young man or woman starting to work in the 1980's is likely to include several major occupational shifts, as specific occupations are made obsolescent by technological change. Even within a line of work, there will be few jobs that are not periodically affected by innovations. These characteristics of occupations and careers will require that the individual often learn new skills and tasks and acquire new knowledge. He will be a learner for much of his life, not only during the years of formal schooling. For this situation, the best preparation

the school can offer is to help the student become an effective independent learner.

Goals

IPI Science is being designed to enable each child to meet the challenges of this extraordinary era. Our aim is to develop a complete individualized science learning system to serve the student from the time he begins elementary school up to his entry into high school. For a science learning system to be complete, it must be consciously and conscientiously directed toward the realization of a set of goals that are attuned to the needs and interests of the student, to the development of the child, and to the circumstances of the 1970's. We have identified such a set of goals for IPI Science. The five goals are listed in Figure 1, and some brief comments about each goal may be appropriate.

The Student Self-Direction Goal emphasizes the concern of IPI Science for developing the student into a competent and confident independent learner. As an independent learner, the student is able to select and utilize a suitable learning environment and instructional materials that will lead him toward desired knowledge, insight, or satisfaction. Moreover, the effective independent learner can specify and follow a fairly long-term plan for his own learning.

The Student Co-Evaluation Goal is also related to the development of the student as an independent learner. In the course of this development, evaluation of the student's learning by a teacher or someone else should decrease over time, and the student should assume continually increasing responsibility for judging how well he performs in learning new information, ideas, and procedures. When a student has become responsible for evaluating his own learning, he can set criteria for the completion or mastery of a learning task and he can recognize that he has completed his task upon meeting these criteria. An independent,

Figure 1

Goals of IPI Science

I. STUDENT SELF-DIRECTION GOAL

The student views the learning process as primarily self-directed and self-initiated.

II. STUDENT CO-EVALUATION GOAL

The student plays a major role in evaluating the quality, extent and rapidity of his learning.

III. AFFECTIVE GOAL

The student displays positive attitudes toward his study of science, scientific inquiry, and the scientific enterprise.

IV. INQUIRY GOAL

The student is skillful in using the processes of scientific inquiry and is able to carry out inquiries.

V. SCIENTIFIC LITERACY GOAL

The student acquires a foundation of scientific literacy.

self-evaluating learner also assesses his program on a learning task as he proceeds. He analyzes the difficulties he encounters, revises his approach if necessary, and seeks out assistance if needed.

The student's attitudes and interests are the focus of attention under the Affective Goal. It is important in planning a science program, we believe, to be explicit about developing student attitudes that are favorable to scientific inquiry and the scientific enterprise. Not only is it important to be concerned about student attitudes toward science in planning a curriculum but also when considering the needs of the child. Holding well-informed, positive attitudes toward science is recognized as an essential ingredient of an individual's ability to live successfully in the contemporary world. In the process of developing attitudes, the student learns to value science for its contributions to man's intellectual growth and to society. He alsc learns to accept the processes of scientific inquiry as a valid way to conduct one's thinking. When carrying on inquiries or confronting problems, the student adopts the so-called "scientific attitudes," which include honesty, open-mindedness, suspended judgment, self-criticism, and commitment to accuracy. We think that a positive attitude toward science is engendered if the student enjoys his science learning experiences in school. Further, the student probably displays both a positive attitude and his interest when he chooses to persue science activities or science-related activities outside of school.

Student involvement in scientific inquiry and the development of skills in using its processes are manifested under the Inquiry Goal. Behaviors pertinent to this goal would be exhibited by the student when he selects and uses appropriate processes of scientific inquiry, both in investigating natural phenomena or solving problems in science and in investigating problems outside of science.

In carrying out an inquiry into any given problem, the student may be observed to formulate a plan for his inquiry, to design procedures which implement his plan, to carry out the indicated procedures, to process the data obtained, to interpret data and observations, and to evaluate the results of the inquiry in relation to its purpose.

Turning to the Scientific Literacy Goal, our concern here is with building that solid base of knowledge and understanding of and about science which the student must have for the sake of his own well-being in today's world. Four components are encompassed in the notion of scientific literacy. First is the behavioral component implied by the common literal meaning of literacy, that the student can describe his observations and experiences with terms drawn from his basic vocabulary of science words. A more fundamental component of scientific literacy is the student's understanding of certain important concepts, principles, and conceptual schemes of science. We consider a scientific idea important if it is relevant. The particular scientific ideas which are included in the curriculum and those which the student elects to study determine the relevance of the content of IPI Science. A third component of scientific literacy concerns the student's realization that scientific ideas change over time and his understanding of other key ideas related to the nature of scientific inquiry. The fourth component, last in this listing but not the least important component of scientific literacy, is the student's understanding of significant ideas related to the social aspects of science. The attention given to this component in IPI Science also contributes to the relevance of the program.

The goals listed in Figure 1, together with the foregoing comments on these goals, represent a kind of composite description of a student near the end of his IPI Science program. The student's attainment of any or all of these goals is, of course, a developmental process. IPI Science, in common with

IPI programs in other areas, assumes that there are identifiable levels in the student's development toward the attainment of the desired goals. We also assume that it is possible to specify most of the student's behaviors related to these five goals at each developmental level in terms of behavioral objectives. Clear and comprehensive specification of objectives is a vital part of an effective individualized learning system. In IPI Science, there are ten levels of student development, Levels A through J, and these are arranged in three principal phases, as shown in Figure 2. In the Exploratory Phase, the child is introduced to various processes of scientific inquiry, and he has many opportunities to sharpen his skills in using these processes as he explores in several different areas of science. In the Inquiring Phase, the main focus is on the child's application of his process skills in problem solving and on his accumulation of knowledge and understanding about himself and his environment. In the Investigative Phase, the child carries out genuine investigations, i.e., inquiries where the answers are not known. He utilizes his process skills and existing knowledge to acquire new concepts, principles, and insights. Also shown in Figure 2 are the approximate current school grades corresponding to the principal phases and developmental levels of IPI Science.

Learning Resources

While it is comforting to have a set of goals and a framework of developmental levels, provisions must obviously be made for suitable and varied means of attaining the several goals of IPI Science. The various types of learning resources available to the student at different levels of IPI Science are listed in Figure 3. Also indicated are the learning resources which contribute to the attainment of each of the five IPI Science goals.

Figure 2

IPI Science Levels and Principal Phases

IPI Science		
PRINCIPAL PHASES	LEVELS	GRADE (approximate)
INVESTIGATIVE	J I H	7-9
INQUIRING	G F E	4-6
EXPLORATORY	D C B A	K-3

Figure 3

Learning Resources of IPI Science

LEARNING RESOURCES	Used in Levels	Contribute to the attainment of..... Student Self-Direction Goal	Student Co-Evaluation Goal	Affective Goal	Inquiry Goal	Scientific Literacy Goal
Individual Taped Lessons (ITL)	A - D				X	X
Individual Lessons (to be read) (IL)	C - G		X		X	X
Directed Group Activities (DGA)	A - E			X	X	X
Student Seminars (SEM)	D - J			X	X	X
Student Activities (SA)	A - E	X	X	X	X	X
Invitations to Investigate (ITI)	D - J	X	X	X	X	X
Self-Initiated Independent Activities (SIIA)	A - J	X	X	X	X	X
Science Learning Games (SLG)	A - J			X	X	X
Science Books (selected readings) (BKS)	A - J	X	X	X		X
Men & Ideas Filmstrips (M & I)	C - J			X		X
Mini-Explorations (MEX)	C - F	X	X	X	X	X
Mini-Investigations (INV)	G - J	X	X	X	X	X
Directed Readings in Science (DRS)	D - J		X	X		X
IPI Science Journal (student publication)	H - J				X	X
Individual Prescriptions (IP)	A - D	X	X			
Guidance and Selection System (GSS)	E - J	X	X			X

To make it possible for a student to progress toward attaining the Student Self-Direction and Student Co-Evaluation Goals, learning resources must be available from which the student may select numerous alternatives for his study or investigation. In addition, the expectations for completion of an activity or the standards for judging mastery of a unit of study must be known to the student, so that he may participate intelligently in evaluating his performance. Learning resources which possess both these characteristics include Student Activities, Invitations to Investigate, Self-Initiated Independent Activities, Science Books (selected readings), Mini-Explorations, and Mini-Investigations. Individual Prescriptions also contribute to the Self-Direction and Co-Evaluation Goals. In the beginning of IPI Science, prescriptions are prepared by the teacher, but the student is increasingly encouraged to write his own prescriptions as he moves through Levels C and D. Finally, the Guidance and Selection System, which will be operative in Levels E through J, is intended to advise and assist the student in directing and evaluating his own learning.

To make possible the implementation of the Affective and Inquiry Goals, it is mandatory to have learning resources which provide some enjoyable experiences for the student in which he can be successful, and resources which offer opportunities for the development of inquiry skills and for abundant practice in inquiry. One indication of our determination about enabling the student to reach the Affective and Inquiry Goals is that all but two of the resources used in IPI Science directly contribute to the attainment of one or both of these goals, as Figure 3 shows.

Contributions to the attainment of the Scientific Literacy Goal are also made by almost all our learning resources. This is hardly surprising, since the locus for most of the program's subject-matter content is in the Scientific

Literacy Goal and learning resources normally deal with some science content. As was previously mentioned, the particular science content which is available for the student to study in IPI Science is a major contributing factor to the relevance of the program. Unfortunately, a complete listing of the subject-matter content of IPI Science cannot be given at this time, since this question is still under discussion. Some key decisions have been made, however, and the gross organization of our science content is already apparent.

In the Exploratory and Inquiry Phases (Levels A through G), the organizing theme for the science content included in IPI Science is:

MAN AND HIS SYSTEMS: <u>NATURAL LIVING SYSTEMS, NATURAL NON-LIVING SYSTEMS, AND MAN-MADE SYSTEMS</u>

Man can think about the natural world as a nested hierarchy of systems and subsystems. Some natural systems are living systems and some are non-living systems. Man himself is a living system with interacting subsystems. And, man creates new systems, in which he may be a participant, and which he can control.

The units of the first two principal phases will focus on, first, man as a living system and, second, the systems that man creates, controls, conceives, and studies. The student's varied experiences with many types of systems lead into his semi-independent and independent inquiries in the Investigative Phase of IPI Science (Levels H through J). Here the organizing theme for the science content is:

<u>THE BIOSPHERE</u>: <u>ECOSYSTEM OF THE EARTH</u>

The biosphere is the thin envelope near the earth's surface where all known living systems normally exist. It is a global ecosystem where natural living systems, including man, interact with each other and with natural non-living systems, and

where man-made systems interact with natural systems and with each other.

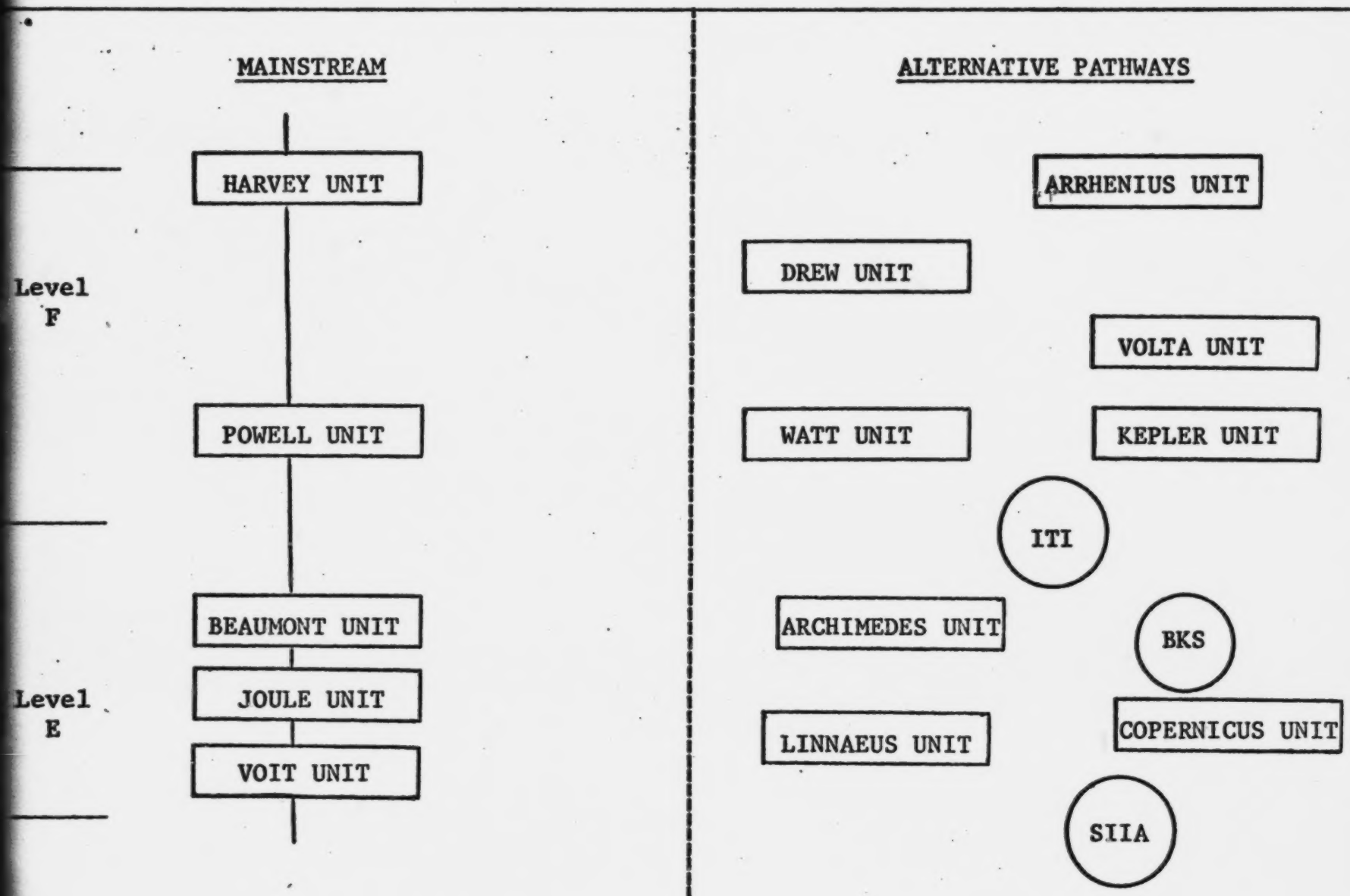
In the units and investigations of the third phase, the content emphasis is primarily on the small-scale and large-scale equilibria in the environment, between the environment and living organisms, and among living organisms. In these units many of the social problems in which science is a sizable component will come into consideration. From his experiences in the Investigative Phase of IPI Science, the student should come to understand and to value the ecosystem in which he lives and to know what he must do to survive in it.

Mainstream and Alternative Pathways

Implicit in the discussion up to this point has been the commitment of IPI Science to individualization, but our organizing notion relating to individualization remains to be made explicit. One type of individualization provided for in IPI Science, as in other IPI programs, is the rate at which the student progresses. IPI allows each student to progress at a rate adapted to his individual learning style and dependent upon how rapidly he masters successive units on a learning continuum. This feature is used in the part of IPI Science called the Mainstream, the common core of science learnings in which every student is expected to achieve mastery. Units of study on the Mainstream are arranged in a sequence. An illustration of the Mainstream organization for Levels E and F of IPI Science is shown in Figure 4. There are five Mainstream units in the E and F Levels. Each unit is identified by the name of a scientist who made some contribution to the field of science that the particular unit concerns itself with. Thus, the Voit Unit is concerned with human nutrition, the Joule Unit with the concept of energy, the Beaumont Unit with the processes of digestion, the Powell Unit with the role of water in

Figure 4

Illustration of Mainstream and Alternative Pathways



Learning Resources used in these units include IL, DGA, SEM, M & I, DRS, MEX.

Learning Resources used within these units include IL, SEM, M & I, DRS, MEX. (Alternative Pathways units are available to the student when he reaches the indicated IPI Science Level and at any time thereafter.)

natural systems, and the Harvey Unit with the circulation of blood in man. Students progress through the units in order beginning with the Voit Unit. Within each unit, and associated with it, various learning resources are utilized, as indicated in Figure 4.

A student may choose to interupt the continuum of these five Mainstream units at any time by selecting one or several of the activities in the Alternative Pathways, also illustrated in Figure 4. There are various possible Alternative Pathways activities available to students working in the E or F Level. Whole units of study, such as the Watt Unit, which is concerned with the expansion and contraction of materials with changes in temperature, or the Linnaeus Unit dealing with the growth of plants from seeds, are available. Each of these Alternative Pathways units arise from possible points of curiosity on the student's part or his desire to know more about topics taken up in the Mainstream units. Other Alternative Pathways activities give the student opportunity to investigate science concepts which may or may not be related to the subject-matter content of the Mainstream units. These activities include Self-Initiated Independent Activities (SIIA), selected readings in science books (BKS), and Invitations to Investigate (ITI).

The notion of Mainstream and Alternative Pathways is used, not only at Levels E and F as illustrated, but throughout IPI Science. As the student progresses through each of the principal phases, he has continually increasing opportunities to select learning experiences in diverse and meaningful Alternative Pathways. By providing both Mainstream and Alternative Pathways resources to meet the needs and interests of the student, we expect that IPI Science will not only be individualized, but also relevant.